

Impact of Clouds on the Atmospheric Absorption of SW – Comparing Theory and Observation at SGP

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ABSTRACT:

This group, and also Li and Trishchenko, have earlier determined the cloud forcing to the atmospheric absorption of SW by combining surface data at SGP with CERES at TOA. Detailed analysis of our results show a systematic trend in the difference of all-sky and clear-sky atmospheric absorption with cosSZA: all-sky absorbs significantly more as cosSZA increases.

From radiative transfer theory, all-sky absorption of SW is expected to be greater (less) than clear sky absorption when clouds are low (high), as cloud scattering increases (decreases) the exposure of solar photons to water vapor in the column. Here we show that the observed trend (aforementioned difference with cosSZA) is consistent with theory. The diagnosis is done with SGP surface and CERES TOA fluxes now on our "CAVE" URL, and also with simultaneous, collocated CERES cloud properties from the Minnis et al. VIRS retrievals. The CERES product CER_SSF TRMM--PFM-VIRS Edition 1 containing VIRS based cloud properties has been released.



Data:

CERES Top of Atmosphere (TOA) Broadband Shortwave Fluxes

TRMM PFM ES8 Product

CERES VIRS Imager based Cloud Properties

Cloud Fraction

Optical Depth

Height

CAVE (Ceres Arm Validation Experiment)

Collection and Archive of Surface and TOA Observations

<http://www-cave.larc.nasa.gov/cave/>

Direct Insolation

Diffuse Downwelling (Adjusted for Nighttime offset)**

Upwelling Shortwave

**Combination of measurements to give
Surface Shortwave Net**

Long-Ackerman Clear Sky Mask

Locations:

ARM (SGP sites **)

***BSRN (Tatano, Florianopolis)**

CMDL(Bermuda, Boulder, Kwajalein, Samoa)

SURFRAD(Bondville, Boulder, Desert Rock, Goodwin Creek)

**Not all have Shortwave Upwelling*

***Adjusted for Nighttime offset*

Time:

January – August 1998

Method:

CAVE Surface observations consist of 30 minute average data. Surface Shortwave NET is computed from the measurements of direct surface insolation, diffuse insolation and upwelling shortwave. The diffuse measurement is corrected by the "nighttime offset**" method to help account for thermal gradients within the instrument. This adjustment is typically less than 5 W m^{-2} and is more important under clear sky conditions.

CERES top of atmosphere TOA broadband shortwave flux measurements from the precessing TRMM spacecraft occur relatively infrequently at any given location and occur with various possibilities of view geometry. The nadir footprint size of the CERES TRMM instrument is $\sim 10 \text{ km}$ this increases as view angle increases. In this analysis we take an average of all measurements occurring with a 30 minute interval whose centroid is within a 15 km radius of the surface station location.

With these toa and surface shortwave net flux measurements we infer shortwave atmosphere absorption.

CERES TOA measurements are radiance measurements that are converted to a flux by means of angular direction models (ADM's) these models are dependent on the scene id of location as well as view geometry. For the Edition2_ES8 product there are 12 scene id possibilities (5 clear, 7 cloudy). Determination of cloud fraction in the ES8 and earlier ERBE products is from the maximum likelyhood estimate (MLE) method. In later CERES releases an increased number of scene id cases will be used, tied to the improvements of cloud property determination available from the VIRS imager. The increased knowlege of scene id will improve the instantaneous accuracy of the toa flux retrieval. The ES8 instantaneous fluxes may contain biases when cloudy sky scenes are sub-divided by cloud properties such as optical depth, phase , height etc.

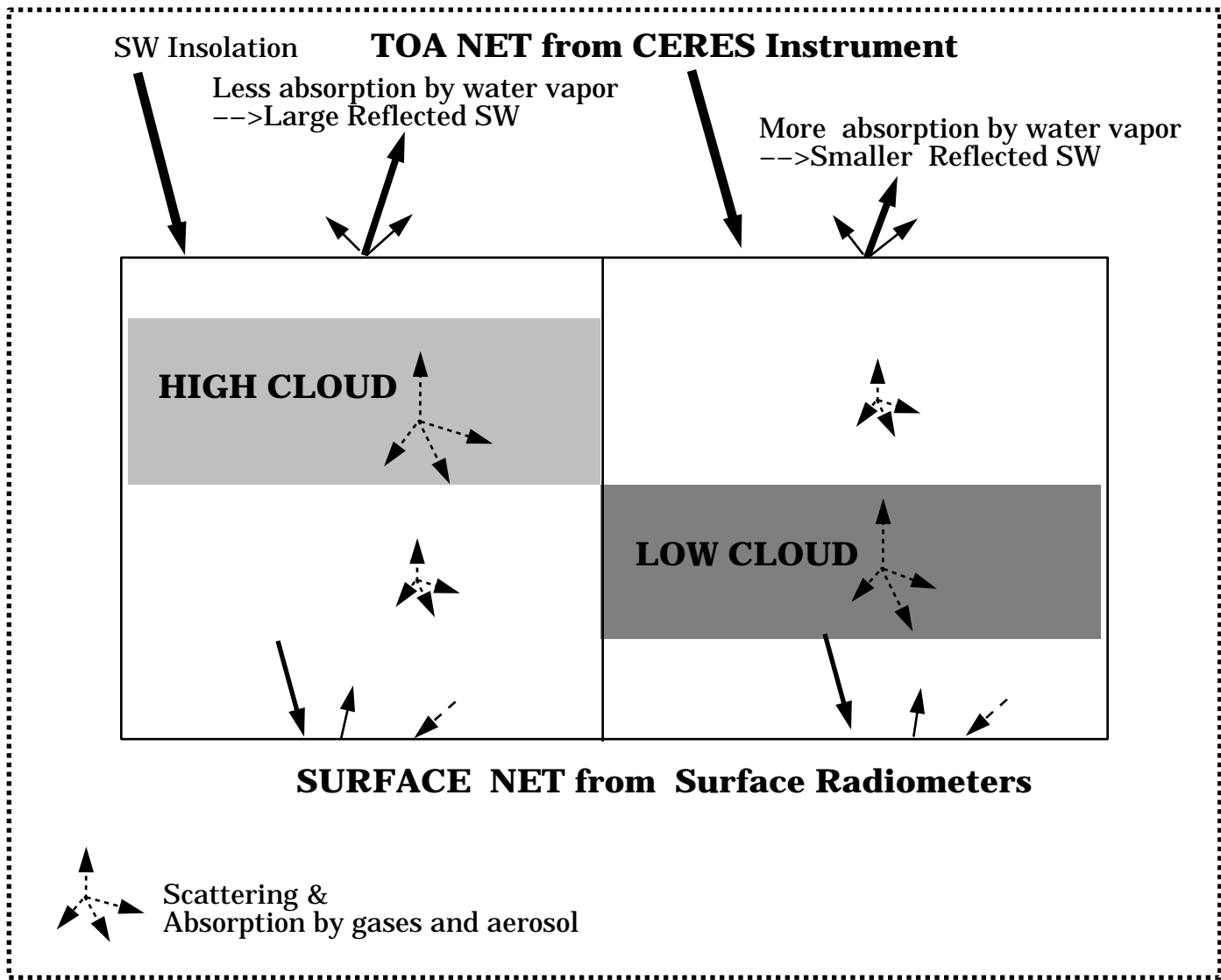
Cloud properties are taken from the CERES Edition1 SSF product. Each footprint is accessed as *clear* and/or up to two sets of cloud properties (height, optical depth, phase , particle size) with associated fractional coverage . Here we use this information to subset the inferred shortwave atmosphere absorption observations.

Also available at many locations is a surface based cloud fraction estimate from the Long-Ackerman method.

** CAVE does this nighttime offset correction for SGP but not all sites.
Several methods for this diffuse correction.

Concept:

$$\text{ATMOSPHERE Absorbed} = \text{TOA NET} - \text{SFC NET}$$



High Sun :

Clouds produce diffuse shortwave which is slightly more susceptible to absorption by water vapor than un-scattered direct insolation.

For a similar optical depth cloud TOA albedo of low cloud is smaller than that of a high cloud, due to absorption occurring above cloud top.

LowSun:

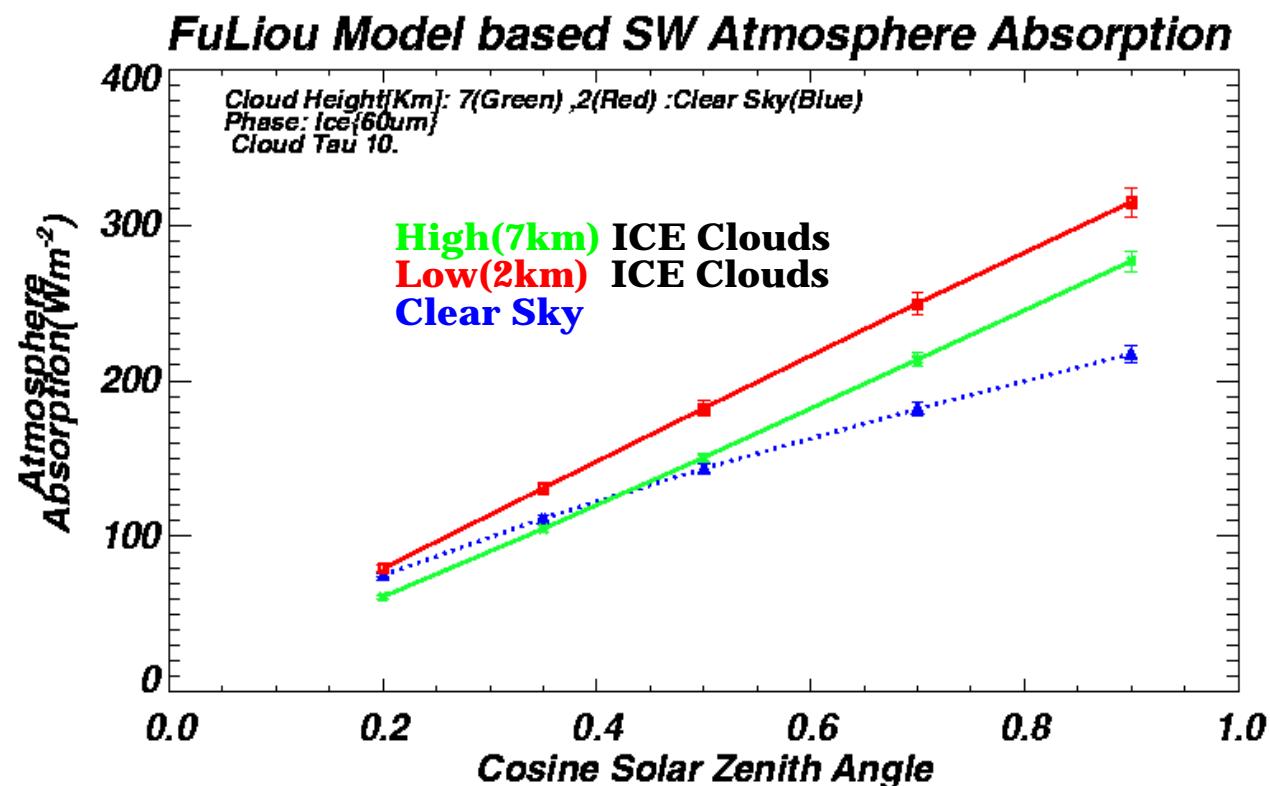
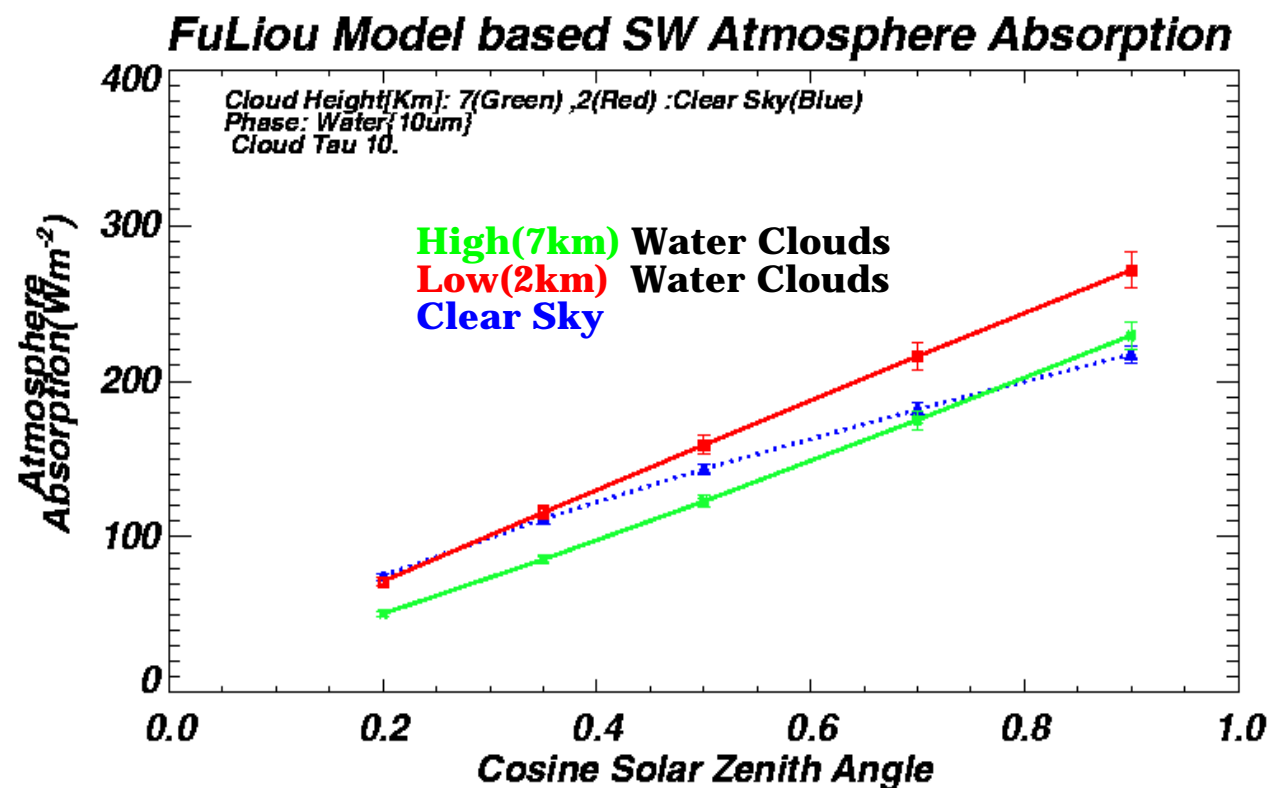
For moderate optical depth clouds relative amount of energy reflected off cloud top is large, reducing diffuse shortwave and associated water vapor absorption.

Reflection by a high cloud sends a photon back to space before it's absorbed by the water vapor below, so atmospheric absorption is then less than for a clear scene.

Ice Vs Water Clouds:

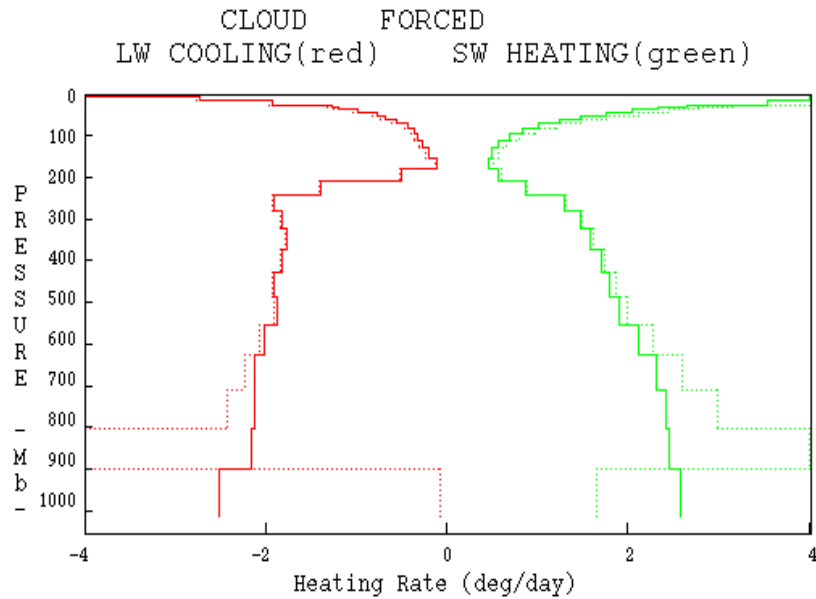
Model calculations show greater albedo and production of diffuse shortwave for ICE phase clouds(60 micron) than Water clouds(10 micron). Increase in diffuse SW results in more atmosphere absorption. Cloud particle size variations are not addressed here.

Idealized Model Sensitivity Calculations: (No VIRS Data used !)



High Sun Angle (CosSol =0.9)

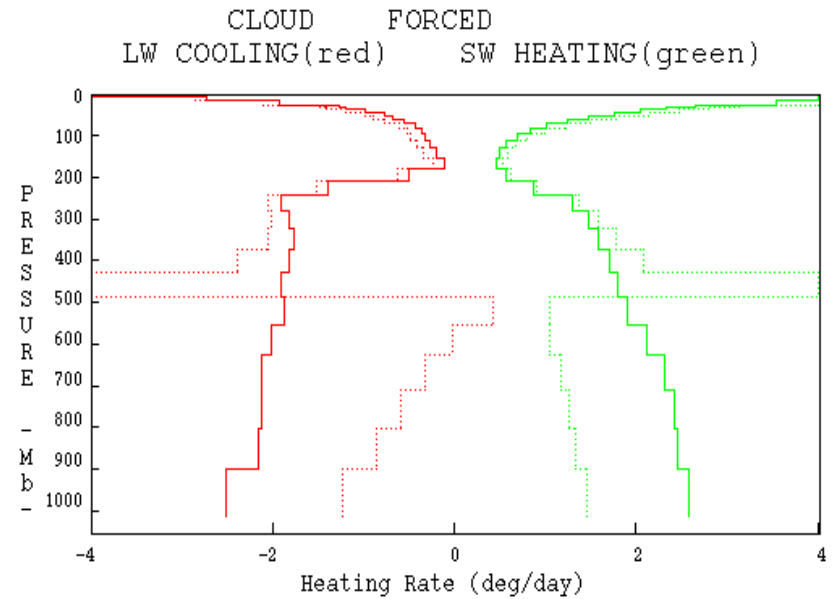
Low(2km) Water(10um) Cloud



Atmosphere State		Fluxes	
		Clear	Forced
Atmosphere	kmIs29.lay	UP TOA SW 149.7	UP TOA SW 314.6
Streams	2	DN TOA SW 1231.4	DN TOA SW 0.0
Phase	WATER	UP SFC SW 93.9	UP SFC SW -41.0
Cos Sol Zen	0.9	DN SFC SW 939.2	DN SFC SW -410.1
Sfc Alb	0.1		
Cloud Level	2		
Cld Particle Sz	10.	UP TOA LW 283.6	UP TOA LW -14.3
Vis Optical Dpt	10.	DN TOA LW 0.0	DN TOA LW 0.0
		UP SFC LW 421.3	UP SFC LW 0.0
Water Path (g/m2)	63.49	DN SFC LW 350.3	DN SFC LW 61.4
Water Cont (g/m3)	0.06486		
Cld Geom Thick(m)	979.		
Cld Top Pres(mb)	802.4		
Aerosol TAU	0.20 0.0		
Aerosol Type	continenta 1.0_dust		
Continuum Type	roberts		
Rayleigh Scatt	ON		
CO2 Conc.(ppmv)	350.0		

$$\text{ATM NET CLOUD FORCED} = (0.0 - 314.6) - (-410.1 + 41.0) = +54.8 \text{ Wm}^{-2}$$

High(7km)Water(10um) Cloud

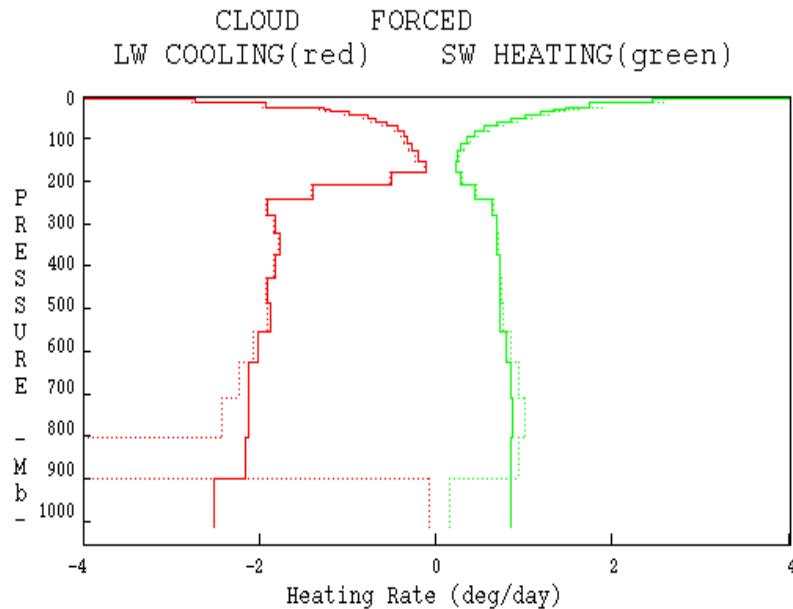


Atmosphere State		Fluxes	
		Clear	Forced
Atmosphere	kmIs29.lay	UP TOA SW 149.7	UP TOA SW 359.4
Streams	2	DN TOA SW 1231.4	DN TOA SW 0.0
Phase	WATER	UP SFC SW 93.9	UP SFC SW -41.5
Cos Sol Zen	0.9	DN SFC SW 939.2	DN SFC SW -414.7
Sfc Alb	0.1		
Cloud Level	7		
Cld Particle Sz	10.	UP TOA LW 283.6	UP TOA LW -76.1
Vis Optical Dpt	10.	DN TOA LW 0.0	DN TOA LW 0.0
		UP SFC LW 421.3	UP SFC LW 0.0
Water Path (g/m2)	63.49	DN SFC LW 350.3	DN SFC LW 34.2
Water Cont (g/m3)	0.06342		
Cld Geom Thick(m)	1001.		
Cld Top Pres(mb)	426.1		
Aerosol TAU	0.20 0.0		
Aerosol Type	continenta 1.0_dust		
Continuum Type	roberts		
Rayleigh Scatt	ON		
CO2 Conc.(ppmv)	350.0		

$$\text{ATM NET CLOUD FORCED} = (0.0 - 359.4) - (-414.7 + 41.5) = +13.1 \text{ Wm}^{-2}$$

Low Sun Angle (CosSol =0.25)

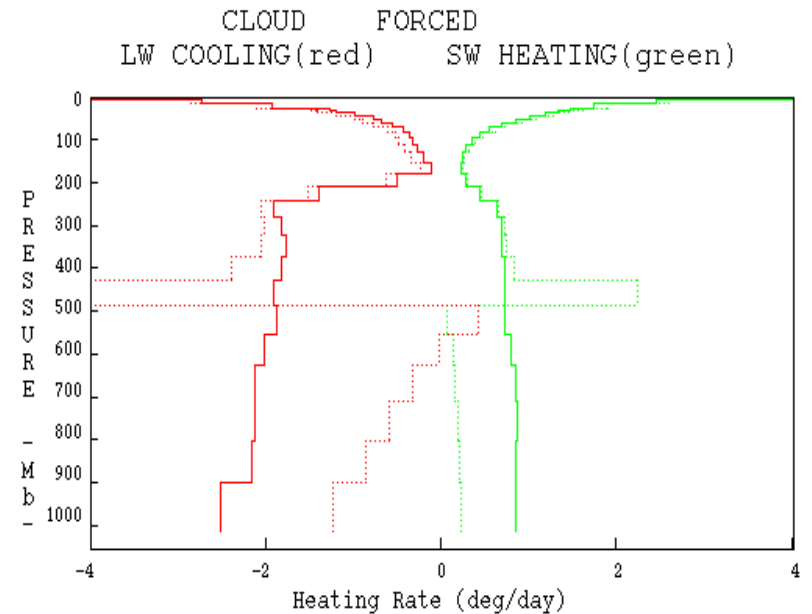
Low(7km) Water(10um) Cloud



Atmosphere State		Fluxes			
		Clear		Forced	
Atmosphere	km1s29.lay	UP TOA SW	72.0	UP TOA SW	106.6
Streams	2	DN TOA SW	342.1	DN TOA SW	0.0
Phase	WATER	UP SFC SW	19.5	UP SFC SW	-11.4
Cos Sol Zen	0.25	DN SFC SW	195.4	DN SFC SW	-114.5
Sfc Alb	0.1				
Cloud Level	2				
Cld Particle Sz	10.	UP TOA LW	283.6	UP TOA LW	-14.3
Vis Optical Dpt	10.	DN TOA LW	0.0	DN TOA LW	0.0
Water Path (g/m2)	63.49	UP SFC LW	421.3	UP SFC LW	0.0
Water Cont (g/m3)	0.06486	DN SFC LW	350.3	DN SFC LW	61.4
Cld Geom Thick(m)	979.				
Cld Top Pres(mb)	802.4				
Aerosol TAU	0.20				
Aerosol Type	continenta				
Continuum Type	roberts				
Rayleigh Scatt	ON				
CO2 Conc.(ppmv)	350.0				

$$\text{ATM NET CLOUD FORCED} = (0.0 - 106.6) - (-114.5 + 11.4) = -3.5 \text{ Wm}^{-2}$$

High (7km) Water(10um) Cloud



Atmosphere State		Fluxes			
		Clear		Forced	
Atmosphere	km1s29.lay	UP TOA SW	72.0	UP TOA SW	128.8
Streams	2	DN TOA SW	342.1	DN TOA SW	0.0
Phase	WATER	UP SFC SW	19.5	UP SFC SW	-11.3
Cos Sol Zen	0.25	DN SFC SW	195.4	DN SFC SW	-112.7
Sfc Alb	0.1				
Cloud Level	7				
Cld Particle Sz	10.	UP TOA LW	283.6	UP TOA LW	-76.1
Vis Optical Dpt	10.	DN TOA LW	0.0	DN TOA LW	0.0
		UP SFC LW	421.3	UP SFC LW	0.0
		DN SFC LW	350.3	DN SFC LW	34.2
Water Path (g/m2)	63.49				
Water Cont (g/m3)	0.06342				
Cld Geom Thick(m)	1001.				
Cld Top Pres(mb)	426.1				
Aerosol TAU	0.20				0.0
Aerosol Type	continenta				1.0_dust
Continuum Type	roberts				
Rayleigh Scatt	ON				
CO2 Conc.(ppmv)	350.0				

$$\text{ATM NET CLOUD FORCED} = (0.0 - 128.8) - (-112.7 + 11.3) = -27.4 \text{ Wm}^{-2}$$

REFERENCES:

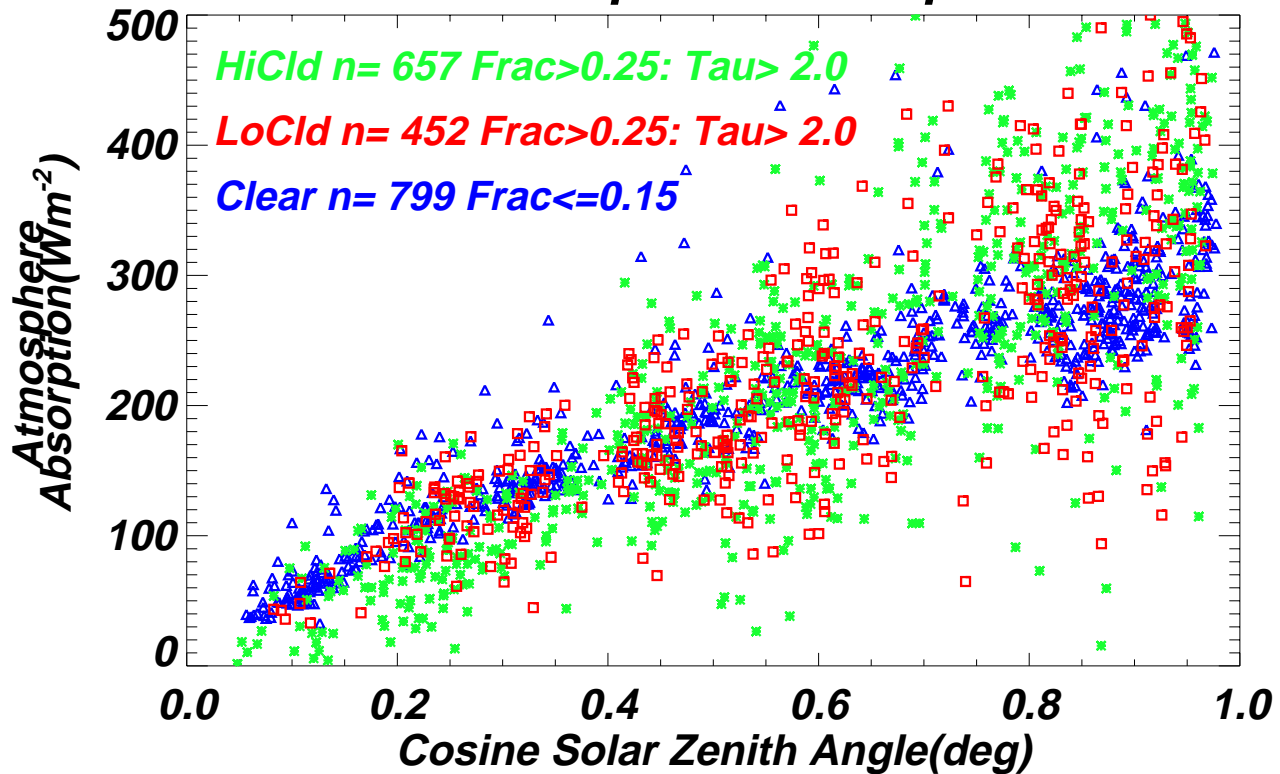
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CERES TRMM (1/98-8/98) : TOA SW NET:ES8

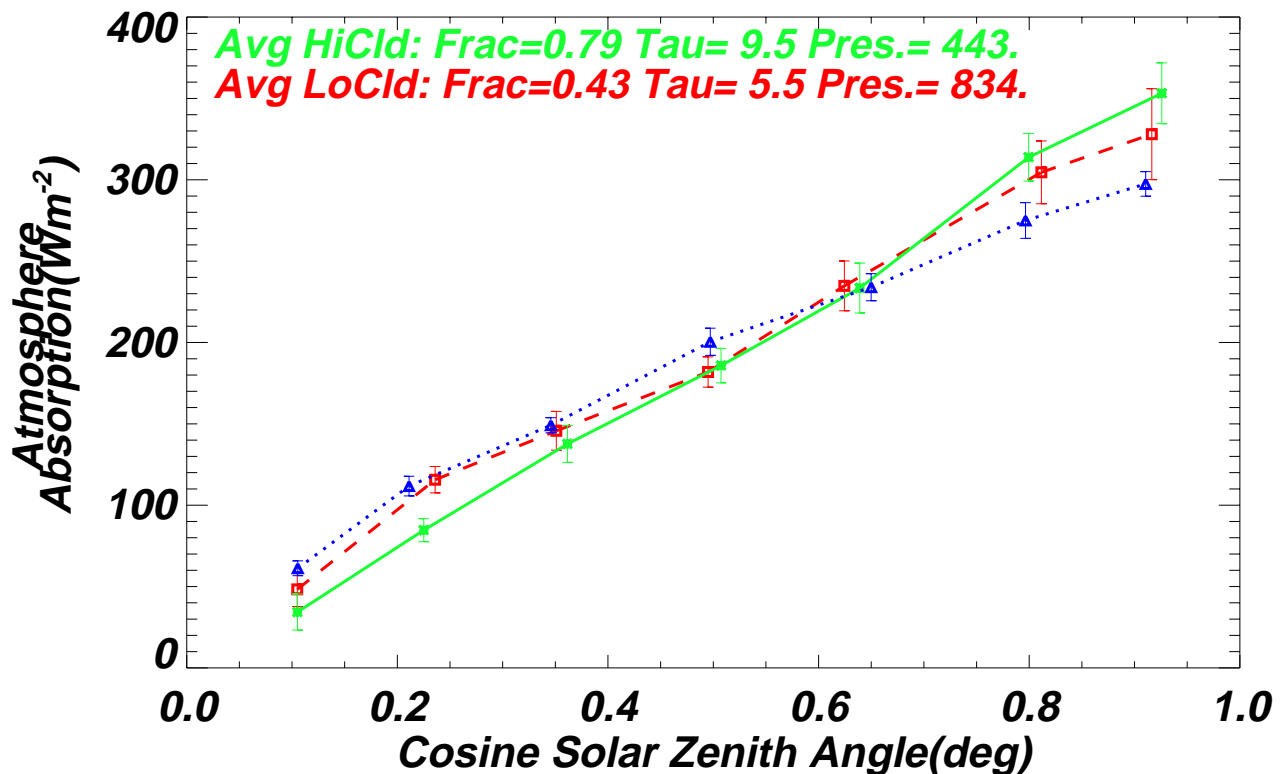
CAVE(ARM:SURFRAD:BSRN): SFC SW NET:(Direct+AdjDiff)-SfcUp

Ceres ES8 product: Satellite based cloud mask

SW Atmosphere Absorption



Mean & 95% confidence interval

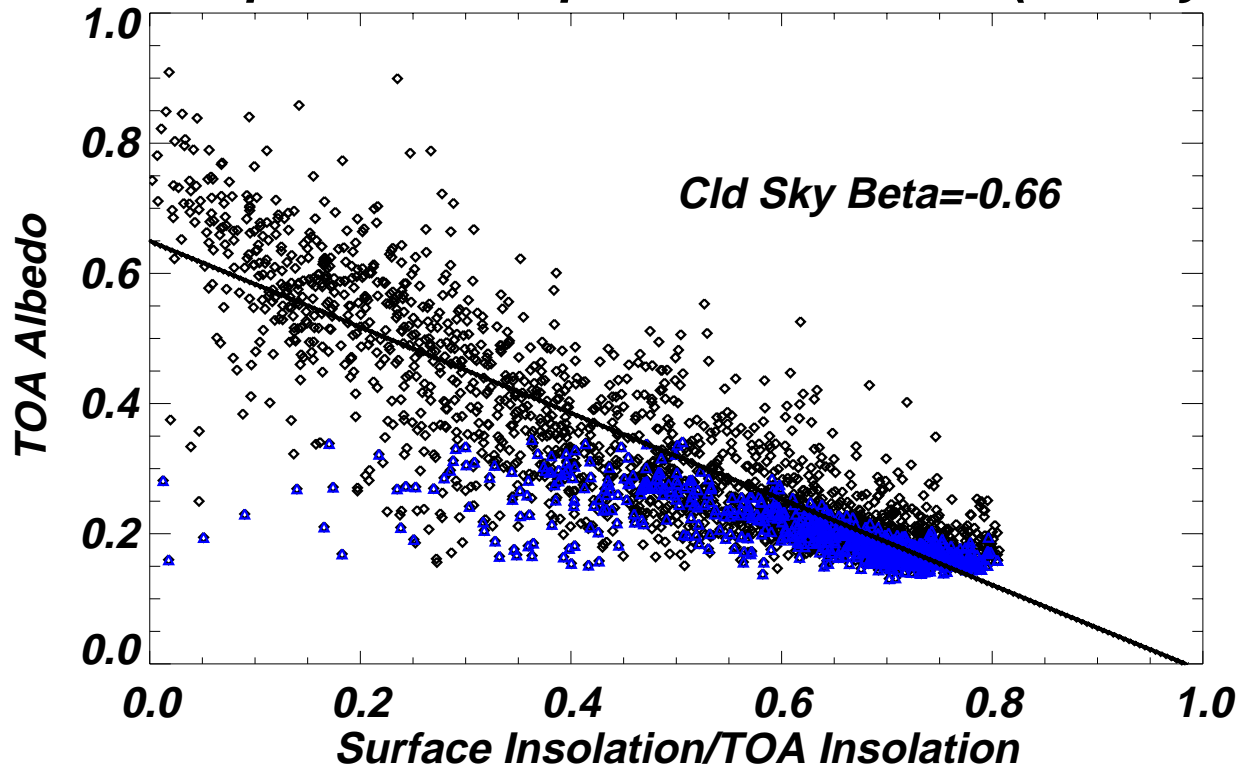


CERES TRMM (1/98-8/98) : TOA SW Albedo:ES8

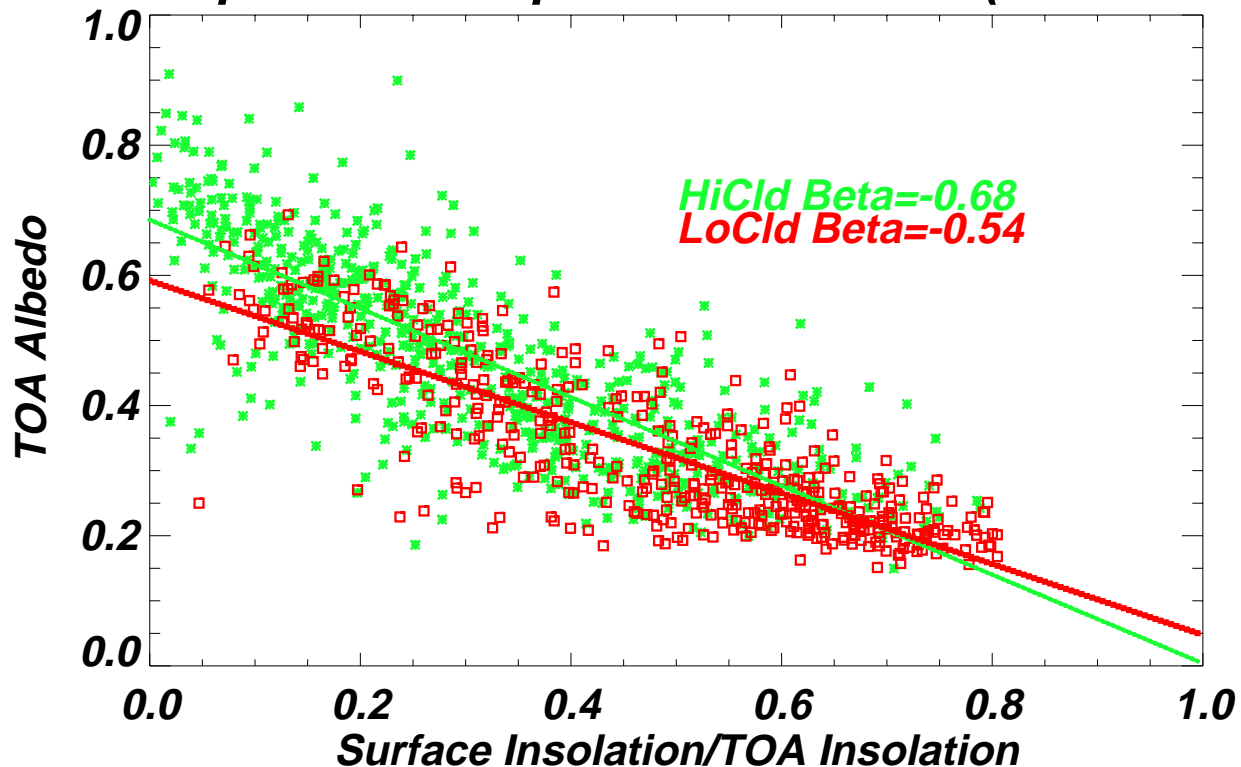
CAVE(ARM:SURFRAD:BSRN): SFC SW Down:(Direct+AdjDiff)

Ceres ES8 product: Satellite based cloud mask

SW Atmosphere Absorption CESS BETA(Cloudy_sky)



SW Atmosphere Absorption CESS BETA(Hi Vs Low Cld)

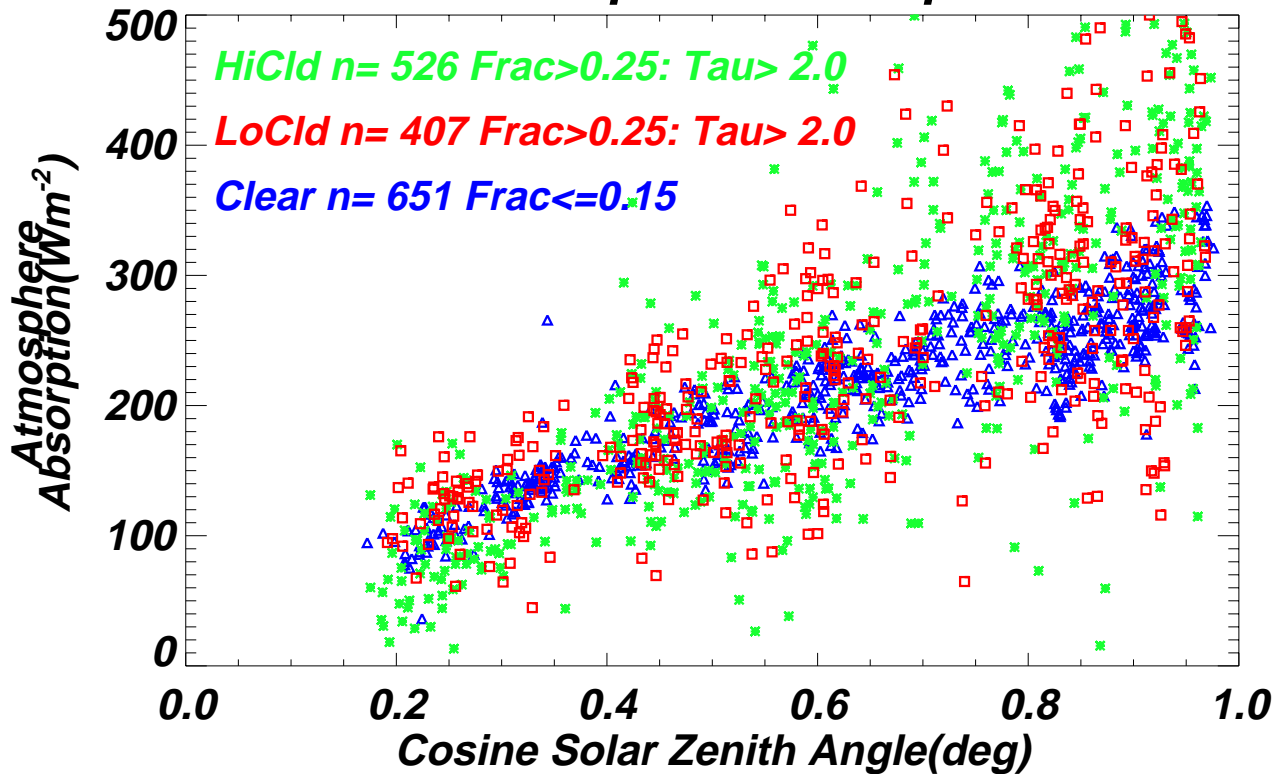


CERES TRMM (1/98-8/98) : TOA SW NET:ES8

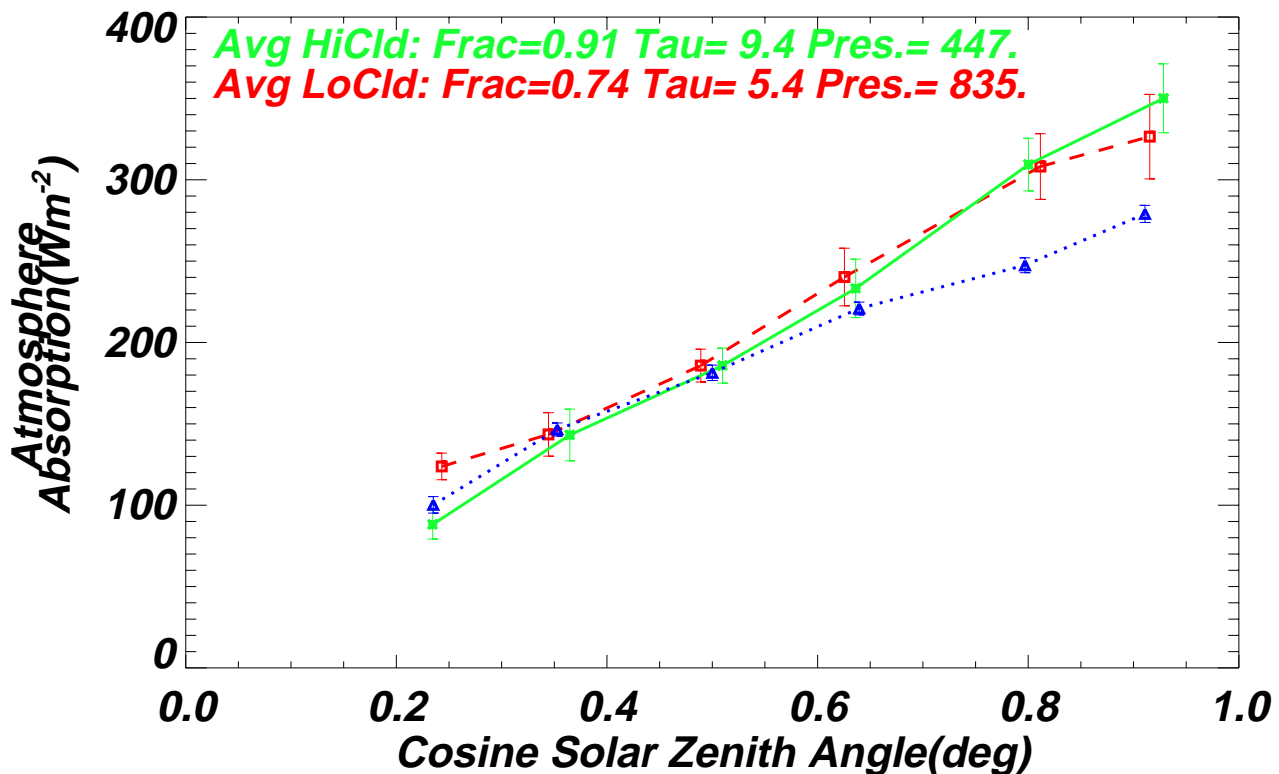
CAVE(ARM:SURFRAD:BSRN): SFC SW NET:(Direct+AdjDiff)-SfcUp

Long/Ackerman Surface based Cloud Mask

SW Atmosphere Absorption



Mean & 95% confidence interval

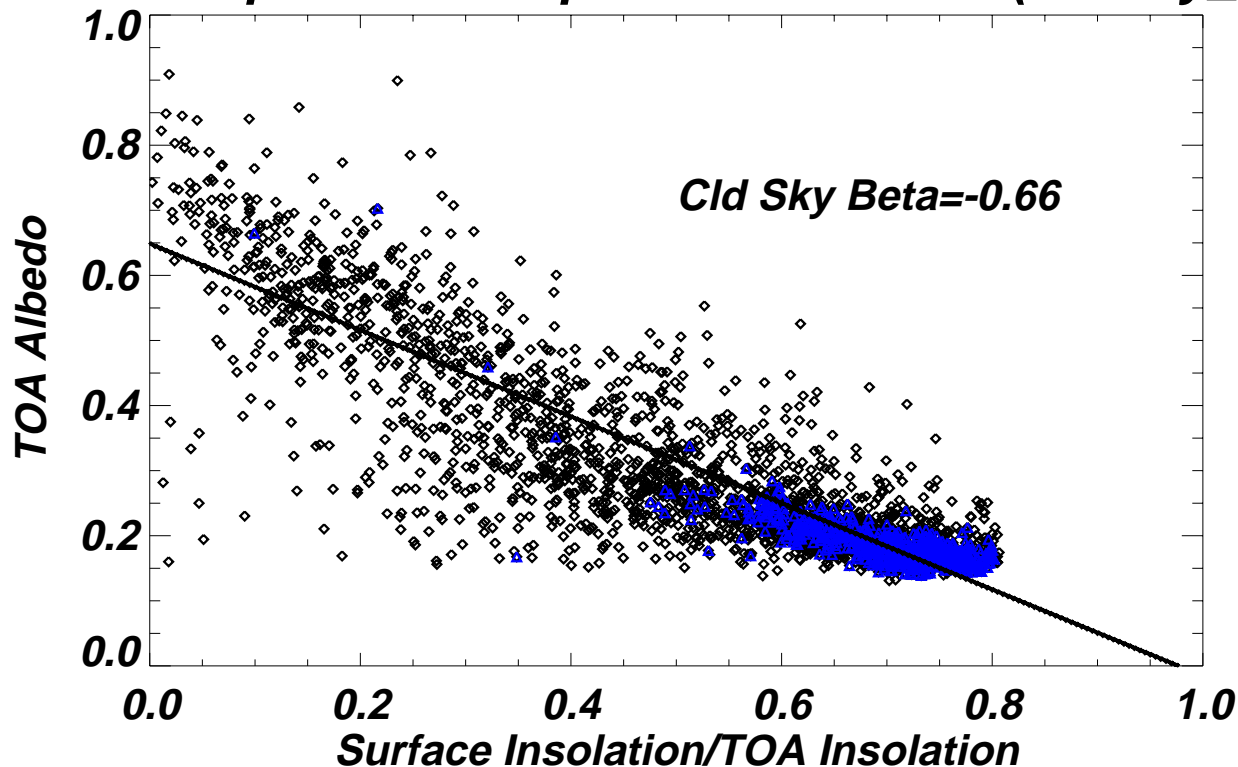


CERES TRMM (1/98-8/98) : TOA SW Albedo:ES8

CAVE(ARM:SURFRAD:BSRN): SFC SW Down:(Direct+AdjDiff)

Long/Ackerman Surface based Cloud Mask

SW Atmosphere Absorption CESS BETA(Cloudy_sky)



SW Atmosphere Absorption CESS BETA(Hi Vs Low Cld)

